THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC

BALLOT SUMMARY

IEEE Project No.____

SPONSOR: SCC-28 BALLOTING COMMITTEE: SCC-28 DATE: 05-14-91

NAME	COMPANY	Classification			Vote Yes	No	Abstain	Not Ret.
Storm, F.K.	U. of Wisconsin			AR	X			
Swicord, M.	FDA/CDRH			R		X		
Yacovissi	Dept. of the Navy			A	X			
Zipse, D.	FMC Corp.			IC	X			
Bassen, H.	FDA/CDRH			RR	X			

A = ADMINISTRATIVE
AR = APPLIED RESEARCH
BR = BASIC RESEARCH
C = CONSULTANT
GI = GENERAL INTEREST
IC = INDUSTRIAL / COMMERCIAL
R = REGULATORY
U/U = USER / UTILITY

Notes:

considerations may apply for multiple exposures (see 8.2.2.1).

8.2.2 Exposure Duration. For a single-pulse laser, the exposure duration is equal to the pulse duration, t, defined at its half-power points. For a cw visible (400 to 700 nm) laser, the exposure duration is the maximum time of anticipated direct exposure, T_{max}. If purposeful staring into the beam is not intended or anticipated, then the aversion response time, 0.25 s, may be used.

For non-visible wavelengths (less than 400 nm or greater than 700 nm), the cw exposure duration is the maximum time of anticipated direct exposure, T_{max}. For the hazard evaluation of retinal exposures in the near-infrared (700 to 1400 nm), a maximum exposure duration of 10 s provides an adequate hazard criterion for either unintended or purposeful staring conditions. In this case, eye movements will provide a natural exposure limitation eliminating the need for exposure durations greater than 10 s, except for unusual conditions. In special applications, such as medical instrumentation, even longer exposure durations may apply.

For repetitively pulsed lasers, the total exposure duration, T, of the train of pulses must be determined. This duration is determined in the same manner as is used for cw laser exposures. The method for determining the MPEs for repetitively pulsed laser exposures is given in 8.2.2.1 and 8.2.2.2. For pulse widths less than 1 ns, see Note in Section 8.

8.2.2.1 Repeated Exposures, Ultraviolet (315 to 400 nm) — Special Considerations. For repeated exposures, the exposure dose is additive over a 24-hour period, regardless of the repetition rate. The MPE for any 24-hour period should be reduced by a factor of 2.5 times relative to the single-pulse MPE if exposures on succeeding days are expected.

8.2.2.2 Repeated Exposures, Visible (400 to 700 nm) and Infrared (>700 nm). Both scanned cw lasers and repetitively pulsed lasers can produce repetitively pulsed exposure conditions. The MPE per pulse for repetitively pulsed intrabeam viewing is $n^{-1/4}$ times the MPE for a single pulse exposure where n is the number of pulses found from the product of the prf and the exposure duration (T) as defined in 8.2.2. (See Figure 12 for a graphical representation of $n^{-1/4}$.) This MPE applies to all wavelengths greater than 700 nm (thermal injury). For wavelengths less than 700 nm, the MPE as calculated on the basis of $n^{-1/4}$ also must not exceed the MPE calculated for nt seconds when nt is greater than 10 s.

For pulse repetition frequencies greater than 15 kHz, the average irradiance or radiant exposure (radiance or integrated radiance) of the pulse train shall not exceed the MPE (as given in 8.2) for a single pulse equal in duration to the pulse train duration, T.

For wavelengths between 400 and 700 nm, the aversion response time, 0.25 s, may be used unless purposeful staring into the beam is intended or anticipated. For wavelengths greater than 700 nm, 10 s may be used as the exposure duration unless purposeful staring into the beam is intended or anticipated.

8.3 MPE for Extended-Source Viewing. MPE values for ocular exposure to extended sources for single pulses or exposures are given in Table 6. All values are specified at the cornea. (See 8.5 for special qualifications and use; see also Figs. 5, 6, and 7.) For multiple pulse lasers or exposures, the MPE is determined using the exposure time of the pulse train duration, T.

8.4 MPE for Skin Exposure to a Laser Beam. MPE values for skin exposure to a laser beam are given in Table 7. These levels are for worst-case conditions and are based on the best available information.

8.4.1 MPE for Skin, Repeated Exposures For repetitive-pulsed lasers the MPEs for skin exposure are applied as follows: Exposure of the skin shall not exceed the MPE based upon a single-pulse exposure, and the average irradiance of the pulse train shall not exceed the MPE applicable for the total pulse train, duration T. (See 8.5 for special qualifications and uses.)

8.4.2 Wavelengths Greater than 1.4 μm. For beam cross-sectional areas between 100 cm² and 1000 cm², the MPE for exposure durations exceeding 10 s is $10{,}000/A_s$ mW/cm², where A_s is the area of the exposed skin in cm². For exposed skin areas exceeding 1000 cm², the MPE is 10 mW/cm².

8.5 Special Qualifications — Infrared. Available data is not sufficient to define wavelength corrections relative to 1.06 μm over the entire infrared range (1.4 μm to 1 mm). At 1.54 μm,

For Partial Body

IEEE 1991 allows up to ~~40~~ 40 mW/cm²

" Frequencies

(5) Gases of different categories (toxics, corrosives, flammable, oxidizers, inerts, high pressure, and cryogenics) not stored separately in accordance with OSHA and Compressed Gas Association requirements.

7.8 Laser Dyes. Laser dyes are complex fluorescent organic compounds which, when in solution with certain solvents, form a lasing medium for dye lasers. Certain dyes are highly toxic or carcinogenic. Since these dyes frequently need to be changed, special care and operating dye lasers. A MSDS for dye compounds shall be available to all appropriate workers.

The use of dimethylsulfoxide (DMSO) as a solvent for cyanine dyes in dye lasers should be discontinued if possible. DMSO aids in the transport of dyes into the skin. If another solvent cannot be found, low permeability gloves should be worn by personnel any time a situation arises where contact with the solvent may occur.

Dye lasers containing at least 100 milliliters of flammable liquids shall be in conformance with the provisions of the NFPA (NFPA 30, 45, and 99) and the NEC (Article 500 - Hazardous (classified) Locations).

7.9 Mechanical Hazards Associated with Robotics. In many industrial applications lasers are employed in conjunction with robots. In these situations, the mechanical safety of the robot installation must be carefully considered.

A number of accidents have occurred where a worker has been pinned between a robot and a confining object ("pinch effect"). The LSO should ensure that approaches to prevent these types of accidents are in place. These approaches may include the use of surface interlock mats, interlocked light curtains, or non-rigid walls and barriers. The installation should conform to recommendations contained in the document ANSI/RIA R15.06-1986 *Standard for Industrial Robots and Robot Systems-Safety Requirements* or latest revision thereof.

7.10 Noise. Noise levels from certain lasers, such as excimer lasers, may be of such intensity that noise

7.11 Waste Disposal. Proper waste disposal of contaminated laser-related material, such as flue and smoke filters, organic dyes, and solvent solutions shall be handled in conformance with appropriate local, state, and federal guidelines.

7.12 Confining Space. In many laser system installations, space is at a minimum. Confining space can be a problem when working around high voltage equipment (see the National Electric Code, Section 110-16). There must be sufficient room for personnel compounded when more than one type of laser is being operated at the same time. Whenever lasers or laser systems are used in confining space, local exhaust, mechanical ventilation and respiratory protection shall be used if LGAC's are present.

7.13 Ergonomics. Ergonomic problems can exist in certain laser operations that can cause unique arm, hand, and wrist deviations. If such repetitive deviations occur for long periods of time medical problems such as carpal tunnel syndrome can arise. The LSO should be aware of this problem and become familiar with appropriate user control measures.

8. Criteria for Exposures of Eye and Skin

Maximum permissible exposure (MPE) values are below known hazardous levels. Exposure to levels at the MPE values given may be uncomfortable to view or feel upon the skin. Thus, it is good practice to maintain exposure levels as far below the MPE values as is practicable.

A limiting aperture shall be used for measurements or calculations with all MPE values. This limiting aperture is required, because the MPE has been expressed (normalized) relative to the limiting aperture area. The limiting aperture is the maximum circular area over which irradiance and radiant exposure can be averaged (see Sections 3 and 9 for selection and application of the appropriate aperture).

The irradiance values for the MPEs in Table 5 can be obtained by dividing the radiant exposure by the exposure duration, t, in seconds. Values for the radi-

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Analysis of Partial Body Method and Why It Should Be Rejected

by David Fichtenberg

Reject the relaxation of power density limits for partial body exposure, it is expected to make people feel very warm or hot, is incompatible with the standard with which it claims compatiblility, and is based on faulty logic, and a dangerous heating of the brain may occur.

(1) There is no compatibility between the proposed relaxation of power density limits for partial body exposure with the standard for "Safe Use of Lasers" [ANSI Z136.1-1986] applicable for shorter waves above those of radio-frequency-and which IEEE 1991 claims compatibility.

For example, the ANSI Z136.1-1986 states,

"For exposed skin areas exceeding 1000 sq centimeters (about 1 sq. foot) the MPE (maximum permissible exposure) is 10 mW per sq. cm. (10 1/1000ths of a watt of power per sq. centimeter)." [Section 8.4.2, pg. 28]

In contrast, IEEE 1991does not have this limit for partial body exposures, but allows a partial body exposure for the general population that is up to 200% of the "laser" standard, while for the higher tier associated with occupational exposure IEEE 1991 has a partial body exposure that is up to 400 % the above laser standard.. As a consequence of IEEE 1991 exceeding this 'laser standard' IEEE can be expected to make people in the general population and the workplace feel very warm or hot.

Given that IEEE 1991 explicitly referenced this Safe Use For Laser standard in justifying its whole body exposure limit, it is unclear why IEEE 1991 then chose to violate this standard and allow up to 4 fold higher exposures than the Safe Use of Laser standard allows. The science based rationale for this is very unclear.

(2) Also, this partial body exclusion relaxation method shoud be rejected because it is based on faulty logic. It is known that some parts of the body if irradiated from a certain position may absorb 20 times more power than the average for the body. Accordingly, if power levels are increased by 20 fold, and if just that part of the body is irradiated and the rest of the body blocked by protective clothing so that it maintains the same contour, (and there is not a major contribution of heating due to induced currents from other parts of the body), then the amount absorbed in that part of the body will be about 20 fold higher than before.

For example, Gandhi et al (1992) computes specific absorption rates (SARs) for the body, by estimating the SARs in individual cubes of 1.3 cm per side, which will be about 1 gram of tissue. See Exhibit for an output showing the SARs when from a far distance the body was irradiated from the front at 915 MHz with a power density of 1 mW/sq. cm. Gandhi found that many cells of tissue by the front of the chest were over 0.6 W/kg gives SAR in mW/kg, so 0.6 W/kg = 600 mW/kg). For example in the first row of cells by the front 5 cells exceed 600 mW/kg (0.6 W/kg). It is easily seens that since the irradiation was from the front it is mainly tissue in the front that has high values of SAR (since 915 MHz does not penetrate more than one to two inches into the body). While some of the SAR may be due to induced currents from other parts of the body, because the chest is so wide, practically all of the SAR value is due to the direct irradiation. Now, according to Table 3 of IEEE 1991 for Relaxations of Partial Body Exposures, for the more restrictive tier the power allowed is 4 mW/sq. cm. Since the output from Gandhi was based on 1mW/sq. cm, to predict what it will be based on 4 mW/sq. cm it is found that:
4 mW/sq cm x 0.6 W/kg (SAR at 1 mW/kg) = 2.4 W/kg. But for the chest tissue, the basic provision of the standard is that tissue should not have an SAR greater than 1.6 W/kg. Hence, using the method offered in IEEE 1991 will in this example result in a 50% excess SAR over that of the basic protection of the standard. Likewise, even greater excesses can occur. One cell in the figure (the cell is circled) has an SAR = 829 mW/kg or 0.829 W/kg. If a power density of 4 mW/kg is applied then the SAR = 3.3 W/kg which is over 200% of the allowed 1.6 W/kg. Hence,

the method proposed in 4.4 apparently does not always apply. It should be rejected and the FCC should not adopt this provision.

Indeed, even the basic logic for the IEEE method seems unusual. Since, in general, tissue closest to the incomming radiation can often be expected to have SARs much higher than the average SAR for the body (as in the above example), it seems quite unusual to suggest that if just a part of the body is irradiated then exposures can 'automatically' be 4 times to 20 times higher. It may be that the entire approach needs to be re-thought.

Incidently, that no documentation is given for the methods used to derive these limits is an important deficiency, especially since it appears the method does not work. This entire section should be rejected by the FCC and rely on current FCC rules which provide for a case by case review to determine if basic protections are maintained.

O.P.Gandhi, "Specific Absoption Rates and Induced Current Distributions In An Anatomically Based Human Model For Plane Wave Exposures", Health Physics, 1992, page 281